

BASS AS AN INDICATOR OF QUALITY

The Relation Between Bass Levels and Quality Perception in Headphones

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ABSTRACT

Bass is a key component in music and its use in modern genres has resulted in lower frequencies generally taking a more prominent role in the frequency spectrum. The preferred level of bass and what is considered as high quality sound is however subjective. This leads to several questions of interest regarding the way we perceive sound quality and how this perception relates to bass levels. With the ambition to explore this, a study was conducted mapping the connection between bass levels and a perception of quality while listening through headphones. Three audio files, representing two different genres of music and one recorded audio book, was edited beforehand with three different levels of bass and then listened to by 41 test subjects in a blind test setting. Test subjects did not get to see or touch the headphones in between versions, which created the illusion of listening to several different headphones when in fact the same headphones were used for all versions and levels of bass. This method, of leading the subjects into believing that they evaluated the headphones instead of different bass levels, changes the scope from only evaluating the bass to instead focusing on the correlation between bass and an overall sense of quality. The results show a positive correlation between high bass levels and perceived quality, where test subjects rated audio with a higher bass level as having higher quality than audio with lower bass levels.

Keywords

Bass; sound quality; quality perception; headphones; frequency response; music

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1. INTRODUCTION

Bass frequencies are important to us. In music bass makes us want to move [6], low frequencies are used to create a sense of presence in movies and in many cultures around the world bass has been used as a conveyer of rhythm in the form of drums and other instruments. Bass frequencies constitutes the lowest part of the frequency spectrum, a popular definition being the range from C0 to C4 in the western chromatic scale, which translates to frequencies between 16Hz and 256Hz. Frequency response in music however, is highly preferential. The amount of bass or treble one prefers may vary substantially from one person to another [7]. In the case of headphones, bass levels are a particularly well discussed topic [9,10], both in regard to the amount of bass reproduced but also how far down the frequency spectrum it is being rendered. Headphones with excessive bass levels may in some cases prove problematic as these frequencies tend to obstruct the audibility of others. The effect being a misrepresentation of the original sound material, assuming that the composer's intention is for all frequencies to be audible. Hence, the aim of this study is to investigate whether high levels of bass has become synonymous with high quality. Specifically, how the perceived sound quality of a piece of music or speech recording changes at different bass levels.

2. THESIS AND PREVIOUS RESEARCH

2.1 Previous Research

Musical instruments that deliver low-frequency sound have been used to create rhythm in music in many cultures through the ages. Why the bass has been given the role of rhythm bearer to such an extent has therefore been the subject of several studies. A recent study [6] shows that this culturally widespread practice might utilize a neurophysiological mechanism in us humans, whereby low-frequency sounds, to a greater extent than high-frequency, affect how we perceive rhythm. This effect is also strongly linked to our motor skills and our ability to move.

A study by Varlet et al [13] researching the relationship between motor skills and auditory and visual rhythm

showed that people had easier synchronization of movements to low-frequency sound than to high-frequency sound. This phenomenon is further investigated in another study [12] where subjects danced to club music with varying volumes on the bass drum. Their movements were measured using motion capture technology showing that with increased volume of the bass drum, the subjects not only danced with larger, more energetic movements, but also had an easier time connecting to the tempo of the music.

Dynamic compression has a long history of use in the world of music. The reason for this is to even out the dynamics of the audio, adapting it to for instance radio or listening in the car [4]. With compression follows the opportunity to subsequently amplify the music, thus creating a piece of music that is perceived as louder than the original track and is more rich in energy, a value usually calculated as RMS energy (Root mean square). This way, the dynamic range is reduced while increasing the perceived volume, also called "loudness". In a study, Hove, Vuust and Stupacher [4] show that hit songs between 1955-2016 have seen an increase in RMS energy, where bass frequencies constitutes the biggest contributing factor, while dynamic range has decreased. This gradual increase in volume, usually referred to as the "loudness war", aims to describe the desire of various record companies and artists to make music as loud as possible, thus having an edge in a music industry characterized by fierce competition. However, new technology such as automatic loudness-normalisation facilities in both broadcast and consumer playback systems, might reduce or even remove loudness as a factor[11].

A not as commonly discussed topic is the effect that the loudness war has had on the frequency reproduction in music, where compression has led to rising levels of both bass and treble. Modern genres such as rock, pop and schlager generally have less dynamic range than older genres such as orchestral music, choral pieces and chamber music, while newer genres contain a greater amount of bass and treble than the older ones [5]. This is something that was taken into consideration in the process of choosing genres for this study.

Several studies [2,3] have explored the impact of frequency response on the experience of music. Gabrielsson et al [2] conducted a study where the perception of music and speech recordings were evaluated after passing through various filters. A test group was asked to evaluate these filtered sounds according to subjective attributes such as clarity, fullness, spaciousness and brightness. A low-shelf filter that increased the level of bass frequencies, much like the one used in our study, made subjects experience sounds as more full and muffled and at the same time less clear, spacious and bright. While Gabrielsson focuses on how these perceived attributes change, the basis for our study is how the frequency range around the bass affects the overall quality experience.

A study [1] shows no correlation between price range and the frequency response of headphones. The test was done on headphones of the type in-ear, supra-aural and circumaural. This was taken into account when choosing headphones for our study.

2.2 Thesis

The main aim of this research report is to examine the effect bass levels have on the perceived sound quality of headphones, hence the main research questions being:

Will an increase in bass be perceived as a marker of high quality, making a piece of music or a pair of headphones sound better or feel more expensive?

Thus, the purpose of this study is to help provide some clarity in the psychology of bass levels. Furthermore exploring whether results vary through different genres of music or in speech recordings.

Our thesis is that sounds more rich in bass will generally be perceived as more qualitative than sounds containing less bass.

3. GATHERING OF DATA

3.1 Method

A study involving 41 test subjects was conducted on April 1-3 2019. Test subjects were divided into three groups, two of which were assigned a genre of music each and the third a speech recording. Genres, pop and classical, were chosen to be as different as possible, thus broadening the scope of the experiment and making it possible to choose songs where the amount of compression varies substantially. The song representing the pop genre was "Anyone out there" by Iselin¹ and the chosen classical piece was "Piano trio no. 3 in C-minor, Op. 101: Andante Grazioso" by Johannes Brahms for piano, cello and violin². Each genre was prepared in three different versions: one with the original bass level and the other two with reduced and enhanced bass levels respectively. Preparations were done in Cubase software using a low-shelf filter, Waves Audio Q10 [13], which increased or decreased bass frequencies by 5dB respectively, with the cut-off point at 200 Hz. The pop-song was the track that varied the most in regard to the amount of bass between versions, and also the one being the most dynamically compressed. The speech recording was a male voice reading of an audiobook played in mp3-format, 154 kBit/s, and all versions of the music tracks were played in mp3-format, 320 kBit/s. All clips used in the study were about 20 seconds long.

The study was conducted with two pairs of headphones, Sennheiser HD600 and AKG K240. The HD600s are considered as being open headphones and the K240s are semi-open which was an important factor since the bass

¹<https://open.spotify.com/track/48wEohztw5FeOboMzIb2LB?si=fkBny39O2GIXbTWne8iGA>

²https://open.spotify.com/track/08IqZxMgLW6Y8vyGYC6WJC?si=JhvfU_4RNOxAKgTku6C-Q

loss of headphones that do not fit correctly is greater with closed headphones than with open headphones. The ease of putting the headphones on was also of importance as well as a varied price point. At the time of the study the Sennheiser headphones had a retail price of 3300 Swedish kr (SEK) and the AKG:s cost 700 SEK.

3.2 Preparatory Test

With the purpose of providing the same perceived volume for all versions of the sound clips used in the main study, a preparatory test was conducted. Seven test participants, not partaking in the main study, listened to several different versions of each of the sound clips in an A/B test-setting and evaluated the perceived volume. The result of the test determined which tracks were then used in the main survey.

3.3 Main Study

During a blind test, participants listened to the same 20-second audio clip in three versions, one of which being the original and the other two were edited in advance with different amounts of bass. Between each version an illusion of changing to a different pair of headphones was created by not letting the participants see or touch the headphones as they were put on and taken off. This aspect, that the participants believe that they evaluate different headphones instead of different bass levels, is important to be able to determine how the level of bass affects the perceived sense of quality in a pair of headphones. Hence shifting the focus from only evaluating the amount of bass to comparing the connection between bass and an overall sense of quality. The use of the same pair of headphones, for all three versions of the track, also minimizes potential factors of error concerning the fit of the headphones and the varying frequency response of headphones. Before each audio clip the interviewer asked if the headphones fit properly around the ear.

After listening to each audio clip, the subjects were asked to fill out a questionnaire with the following four questions:

- How did you experience the sound quality?
- How did you experience the bass levels?
- How did you experience the treble levels?
- How much do you think the headphones cost?

For the first three questions, the subject answered on a scale from one to ten. The ends of the scale, 1 and 10, were described as "Very poor" and "Very high" for the first question and "Very weak" and "Very strong" for the second and third question. For the final question three options were given: Less than 1000 SEK, between 1000 and 2000 SEK and more than 2000 SEK.

3.4 Test Group

The test group consisted of 41 college engineering students, all of which majored in Media Technology at the Royal Institute of Technology in Stockholm. Subjects were between 19 and 29 years old, all of them perceived themselves to have normal hearing and their experience of listening to music and speech in headphones varied.

The test group was divided into three subgroups, each being assigned a genre. The pop song and the audiobook was listened to by fourteen people each and thirteen people listened to the classical piece. Half of the test group started with the Sennheiser headphones and the other half with the AKG:s. In order to minimize possible sources of error that may arise from the audio tracks being played in a certain order, the tests were arranged so that all possible orders had equal representation. Adding the option to play either the AKG headphones or the Sennheiser headphones first, result in the following calculation:

$$3! \text{ possible orders} * 2 \text{ headphones} = 12 \text{ different orders}$$

Hence the audio clips were played in a total of 12 different orders.

4. RESULT

Test data from the different series were compared and analyzed focusing on differences in the mean values between the original audio clip and the other two clips. Results regarding the perceived sound quality and cost are thoroughly reviewed, while answers from the bass and treble questions are compared briefly with the other data. To test the significance, Anova tests were used.

4.1 Analysis of Perceived Sound Quality

	Reduced bass (-5dB)	Original	Increased bass (+5dB)
AKG	6,27	6,66	7,24
Sennheiser	6,32	7,22	7,41
All answers	6,29	6,94	7,33

Table 1. Mean value table for the question "How did you experience the sound quality?", Where possible answers range from 1 (very poor) to 10 (very high). Divided by headphones and all answers.

4.1.1 All Responses

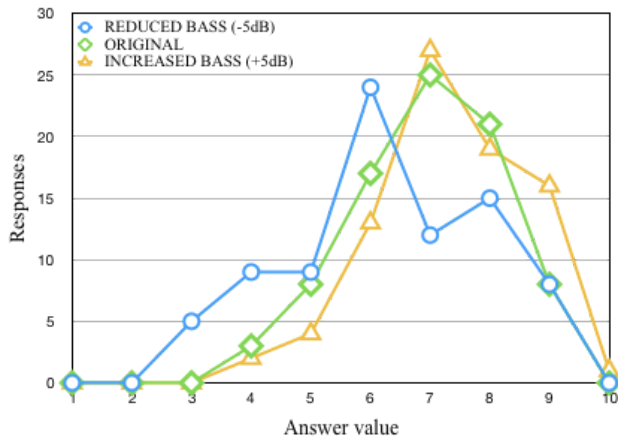


Figure 1. The result of all answers to the question "How did you experience the sound quality?" for the different audio clips. Answer value 1 corresponds to (very poor) and 10 to (very high).

The result of all 82 responses, across all three genres and in both headphones, shows that the soundtracks with enhanced bass levels produced slightly higher values than the originals. As shown in Figure 1, both versions had the largest amount of responses at value 7. The bass enhanced version however generated more of the higher values on the scale producing the higher mean of 7.33 compared to 6.94 for the original tracks, as shown in Table 1. A significant difference can be established at 5% between the originals and the tracks with the enhanced bass ($p = 0.0497$).

The tracks with reduced bass levels generally show lower values than the other two, which is reflected in the lower mean of 6.29. A test of significance as the one above, between the original and the reduced bass tracks, also show a significant difference ($p = 0.0059$).

Following the analysis of variance, we can therefore determine a significant difference in the experience of sound quality, at a significance level of 5%. This is true in both the comparison between the bass-reinforced audio clips and the originals, as well as between the originals and clips with reduced bass levels.

When looking at the results from the two kinds of headphones used in the study separately, shown in Table 1, it's apparent that they follow the same trend as for all answers combined. Statistical significance can be established at 5% between all series except when comparing the bass reduced tracks with the originals in the case of the AKG:s, and in the comparison between the originals and the bass-enhanced tracks in the case of the Sennheisers.

4.1.2 Responses Divided by Genre

The results regarding the classical piece, presented in Table 2 and Figure 2, show that listening to the song with more prominent bass generally received higher

	Reduced bass (-5dB)	Original	Increased bass (+5dB)
Classical	6,85	6,81	7,38
Pop	5,36	6,71	7,00
Audio book	6,71	7,29	7,61
All answers	6,29	6,94	7,33

Table 2. Mean value table for the question "How did you experience the sound quality?", where possible answers range from 1 (very poor) to 10 (very high). Divided by genre and all answers.

response values than the remaining versions. The average value for this is 7.38, while the original and the reduced bass sound clip received an average of 6.81 and 6.85 respectively. However, comparison of these test series does not meet the requirement for significance at the level of 5% ($p > 0.05$).

When looking at the results from the question about sound quality regarding the generally more bass rich pop-genre, it is apparent that the differences in perception of sound quality between the different versions are greater. As shown in Table 2, the bass amplified sound clip gets the highest average of 7.00 followed by the original at 6.71. However, this difference can not be viewed as significant ($p > 0.05$). The version with reduced bass levels is experienced by the test group as much poorer in sound quality and receives an average value of 5.36. The difference between the test group's experience of this audio clip versus both the original and the clip with increased bass levels is significant at 5% ($p < 0.05$).

Mean values for the perception of the sound quality regarding the audio book reading, also shown in Table 2, follow the same pattern as most other series in the experiment, ie the track with enhanced bass levels gets a higher average value than the original track and the one with reduced bass. The bass-enhanced track receives an average of 7.61, while the original and the bass-reduced audio clip receive an average of 7.29 and 6.71 respectively. Significance tests between these different versions show that there neither is significant difference between the lowered bass version and the original, nor between the original and the reinforced version ($p > 0.05$). A statistical comparison between the track with reduced bass and the one with enhanced bass, however, shows a difference in experience, at significance level 5% ($p < 0.05$).

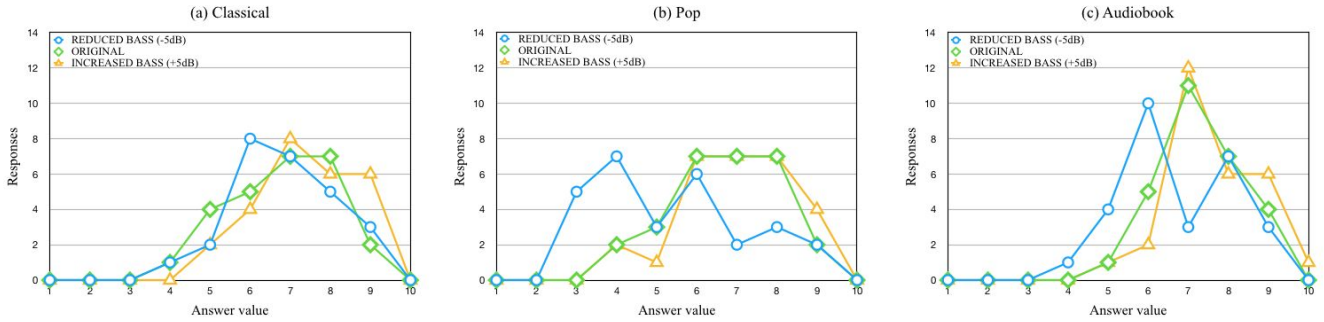


Figure 2: The result of answers to the question "How did you experience the sound quality?" for the different audio clips when listening to the genres classical (a), pop (b) and audiobook (c). Answer value 1 corresponds to "Very poor" and 10 "Very high".

4.2 Analysis of Presumed Price Range

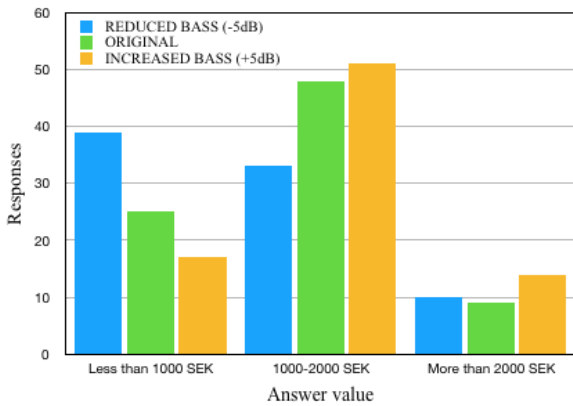


Figure 3. The result of all answers to the question "How much do you think the headphones cost?" for the different audio clips.

4.2.1 All Responses

For the question "How much do you think the headphones cost?" there were three response options, "Less than 1000 SEK", "1000-2000 SEK" and "More than 2000 SEK". The results show that both headphones used in the test are perceived as being a bit more expensive by the test group while listening to sound clips with boosted bass, followed by the original versions and finally those with reduced bass. The difference is slight however. As shown in Figure 3, tracks with lowered bass generated the most results on response option 1 "Less than 1000 SEK", while the original versions and those with increased bass received most answers on alternative 2 "1000-2000". However, versions with increased bass received more answers to option 3 "More than 2000 SEK" than the originals. If these response options are labeled as 1, 2 and 3 as described above, the tracks with reduced bass receive an average of 1.65 for both headphones combined. The original versions receive an average of 1.80 and those with increased bass receive an

average of 1.96. However, an Anova test shows that the only difference that can be considered statistically significant ($p < 0.05$) is the one between the tracks with reduced bass and those with boosted bass levels. For the others, no statistical difference was seen ($p > 0.05$).

4.2.2 Responses Divided by Genre

When looking at the results from the question about the presumed price range separated by genre, one finds that all genres follow the same trend as the results for the entire test group. Thus, the headphones are perceived as the most expensive while playing the bass-enhanced audio tracks, a little cheaper when playing the tracks in the original version and even cheaper while playing the bass-reduced tracks. The biggest difference is seen in the pop genre. Using the same scale as above, naming the categories 1, 2 and 3, gives an average of 1.43 for the reduced bass track, 1.75 for the original version and 1.96 for the amplified bass track. However, an Anova test shows that there is no statistically significant difference between the versions at a significance level of 5%, in any other case than between the bass-reduced track and the bass-enhanced.

4.3 Bass and Treble Levels

	Reduced bass (-5dB)	Original	Increased bass (+5dB)
Bass level	4,82	5,94	6,66
Treble level	6,23	5,95	5,85

Table 3. Mean value table for experienced bass and treble levels.

Between each audio clip the test subjects were asked to answer the questions "How did you experience the bass level? (Low sounds)" and "How did you experience the treble level? (High sounds)". In both cases, options

ranged from 1 to 10, where 1 corresponded to very weak and 10 to very strong.

As shown in Table 3, analyzing the answers to the question about bass level shows that the mean value of the perceived bass level varies according to the prepared variation of the track. Worth noting is that the result from the question about the bass experience follows the same trend as the one about sound quality. As for the question about the perceived treble, the mean level of the perceived level decreases as the bass level increases.

5. DISCUSSION

With the purpose of contributing to the research regarding bass and how the perceived sound quality varies when changing it, we considered the question: "How do bass levels affect the experience of quality when listening through headphones?". The overall result from the study reinforces our thesis, that increasing bass levels leads to an increase in perceived quality. How results vary across different genres and how bass level correlates with an assumed price were also explored to form a more holistic view.

To gain a more definite result, a larger test group would have been preferred. In our opinion this is problematic because when analyzing the answers by different factors, by genre for example, we could see a clear trend in the mean values that increased amounts of bass led to a perception of better sound quality. However, these trends could not always be statistically proven, a contributing factor being the low number of responses.

Although we were able to show the positive effects increased bass levels have on the perceived sound quality when analyzing all answers, the same can not be said for all genres separately. The track in which the perceived sound quality varied the most between the different bass versions was the pop song, which is interesting considering it is the track already containing the lowest frequencies of bass. Raising or lowering the bass levels therefore gives a more noticeable effect than in other genres, as more information is available at low frequencies. The classical piece lacks deep bass, when compared to the pop song, and therefore the effect of different bass levels is harder to perceive. This is also reflected in the results, where we see that the classic genre is the one varying the least in perceived sound quality between the different versions of the song.

We also examined the difference between how bass levels affect the quality in music in contrast to in speech. Although not statistically determined, both the music and speech tracks follow the same trend as previously mentioned where an increase in bass gave a higher assessment of the sound quality.

In order to provide a more generally applicable result, rather than for only one pair of headphones, tests were conducted using two pairs of different headphones. A more comprehensive result could have been achieved with a larger number of headphones. This would, however, have required a substantially larger test group,

which unfortunately was not possible to acquire within the framework of this study.

The question about the assumed price only had three relatively large categories, which may have made the process of obtaining a well-substantiated result more difficult, as well as making findings problematic to prove statistically. With a larger set of response options, nuances in the presumed price difference could have been better accounted for. Categories in higher price ranges may also have been a good addition, to cover the high end range of headphones. As is, no conclusion can be drawn from the result of this question, other than a statistical difference between the bass-reduced tracks and those with increased bass levels, where the latter are perceived as more expensive. This fact is also true if you look at the results from the headphones separately. With a larger test group and, as mentioned above, more response options, one might be able to establish statistically significant results from the trends found through analysis of the mean values. Consequently, regarding how the headphones price was estimated, our results are in line with previous research [1], in that no direct correlation between bass level and cost was found.

Results from the question about how the bass level was perceived was consistent with the actual change between the audio clips, which indicates that subjects were aware of the changes in bass level. A problem discussed in the introduction is that an overemphasized bass tends to overshadow other parts of the frequency spectrum. If bass frequencies constitutes too large a part of the total frequency reproduction in headphones, musical works might not receive the auditory representation the author intended, as certain frequencies are not represented. The results of the question about how the level of treble was perceived shows a mean value decrease as bass level (both perceived and actual) increases. This gives an indication that an oversized bass does have a tendency to take over the soundscape, making it harder to perceive other frequencies to the same extent, in this case specifically the treble.

It should be borne in mind that the test group used in this study should not be considered representative of an entire population, since the interest of sound and music can be assumed to be somewhat higher than average in media technology students. In terms of listening experience, however, there is research to support that experienced and inexperienced listeners generally prefer the same speakers in a blind test [8]. The age range of the test group, 19-29 years, can also be considered a source of error, as research [9] shows that age is an important factor to bass and treble preference. Younger people, according to the study, generally appreciate a greater amount of bass and treble than the older people. So although the results of the study therefore cannot be assumed to be generally applicable, it can however, give a strong indication of the effect of bass levels on the perceived sound quality.

So what does this result, that we appreciate bass-heavy sounds more than others, mean? It may have something

to do with being indoctrinated by developments during the second half of the 20th century and onwards, where modern genres have gained an ever more pronounced bass [4], creating in us a preference for a more prominent low-end. Genetic reasons might also be speculated in, as studies [6,13] show that the brain responds to bass frequencies in a different way than to other frequencies, especially when it comes to rhythm and motor skills.

6. CONCLUSIONS

Through the results of our study we see a positive correlation between bass levels and a perception of quality when listening through headphones. This correlation applies to a total result across music genres pop and classical music as well as an audio book speech recording. However, results are unclear in terms of the genres individually, largely due to the size of the test groups. The design of the test group should also be taken into account, as results can be considered valid only for the demographic group represented in the study, ie college students. No clear link between bass levels and the presumed price range of the headphones could be established by the result.

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